D9.9: Regulation and standards recommendations on electric infrastructure charging

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T9.7: - Regulation and standards recommendations

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Technical References

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Document history			
V	**Date**	**Partner(s)**	**Action**
V0.1	08/03/24	CIRCE	Table of Content avaible
V0.2	20/04/24	All	Subsections .1 and .2. Contribution from all partners
V0.3	20/05/24	All	Subsections .3 and .4. Contribution from all partners
V0.4	01/06/24	CIRCE	First draft version
V0.5	07/07/24	All	Update with the final results from conductive demos
V0.6	05/08/24	All	Update with the final results form inductive demos
V1.0	20/08/24	CIRCE	Final Quality Review

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EXECUTIVE SUMMARY

This document is the deliverable "D9.9: Regulation and standards recommendations on electric infrastructure charging" of the H2020 project INCIT-EV (project reference: 875683).

This document compiles a series of suggestions for the governmental bodies of Europe. These suggestions aim to enhance understanding of the regulatory changes required for the successful and cost-effective integration of actions for a widespread adoption of electric vehicles.

In this task, recommendations have been provided concerning the standardization and regulation of electric mobility. Two main standardization needs have been addressed: (i) the absence of standardized regulations that could promote innovation within a specific realm and (ii) the requirement to reassess or broaden specific standards or regulations. Upon the completion of all showcased use cases and their respective impacts being integrated into the DSS, a series of suggestions have been released to hasten the updates of European and global regulations pertaining to charging technologies, urban and vehicular adaptations.

The delivery of this deliverable is done in accordance with the description in the Grant Agreement Annex 1 Part A with 2 months of delay and no content deviation from the original planning.

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ACRONYM LIST

Table 1. Acronym List

Acronym	Definition
EU	European Union
EV	Electric Vehicle
AV	Autonomous Vehicle
CAV	Connected Autonomous Vehicle
VA/GA	Vehicle Assembly / Ground Assembly
WPT	Wireless Power Transfer
WPTS	Wireless Power Transfer System
D-WPT	Dynamic Wireless Power Transfer
H-WPT	High-power wireless power transfer
EMC/ EMF	Electromagnetic Compatibility / Electromagnetic Fields
AC	Alternating Current
DC	Direct Current
IEC	International Electrotechnical Commission (Standardization body)
SAE	Society of Automotive Engineers (Standardization body)
UL	Underwriters Laboratories (Standardization body)
ISO	International Organization for Standardization (Standardization body)
ICNIRP	International Commission on Non-Ionizing Radiation Protection
EM	Electromagnetic
IPT	Inductive Power Transfer
V2G	Vehicle to Grid

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Acronym	Definition
OEM	Original Equipment Manufacturer
PKI	Public Key Infrastructure
CA	Certificate Authority
HVDC	High Voltage Direct Current
CEI	Italian Electrotechnical Committee (Standardization body)
DSO	Distribution System Operator
OCPI	Open Charge Point Interface
CPO	Charging Point Operator
VAT	Value-Added Tax
eMSP	eMobility Service Provider
EVSE	Electric Vehicle Supply Equipment
MCS	Megawatt Charging System
TSO	Transmission System Operator
OCA	Open Charge Alliance
WG	Working group
ACER	Agency for the Cooperation of Energy Regulators

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1 INTRODUCTION

1.1 Background

Today, the lack of attractive business models for charging infrastructures are hindering the EVs EU-wide deployment. INCIT-EV aims to demonstrate an innovative set of charging infrastructures, technologies, and its associated business models, ready to improve the EV users experience beyond early adopters, thus, fostering the EV market share in the EU. The project is setting up 5 demonstration environments at urban, peri-urban and extra-urban conditions for the deployment of 7 use cases, addressing:

1.Smart and bi-directional charging optimized at different aggregation levels

2.Dynamic wireless charging lane in an urban area

3.Dynamic wireless charging for long distance (e-road prototype for TEN-T corridors)

4.Charging Hub in a park & ride facility

5.Superfast charging systems for EU corridors

6.Low power DC bidirectional charging infrastructure for EVs, including two-wheelers

7.Opportunity wireless charging for taxi queue lanes in airports & central stations

These use cases pursue innovations in the current charging solutions as well as their seamless integration into the existing transport, grid, ICT, and civil infrastructures. For this purpose, the INCIT-EV Platform will be developed comprising a DSS and a set of APPs addressing the users' and e-mobility stakeholders' needs.

1.2 Objective

This task focuses on identifying and recommending necessary changes to standardization and regulatory frameworks to foster the wide-scale adoption of electric mobility. The recommendations aim to address two main types of standardization needs:

- Lack of standardization: identifying areas where the absence of regulations is hindering innovation.
- Review and extension of standards: suggesting revisions or extensions to existing standards to improve the legislative framework.

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2 METHODOLOGY

The methodology for this task has been structured to systematically address the regulatory and standardization needs for the deployment of EV charging infrastructure. The following steps outline the approach taken:

- Identification of technology developments:

  The first step involved identifying the technological advancements relevant to electric vehicle (EV) charging, mainly the ones involved in the project.

- Partners distribution:

  Work was distributed among partners based on their project roles, expertise and participation in project demonstrators. This ensured that each aspect of the task was handled by the most knowledgeable and experienced partners, leveraging their specific competencies.

- Iterative process of standards analysis:

  An iterative process was employed to analyse existing standards, legislations and related documents. This process involved multiple cycles of review and refinement to ensure thorough analysis and identification of key issues.

  Partners conducted detailed assessments of current standards and regulations, focusing on their applicability, limitations and potential areas for improvement.

- Identification of normative limits and gaps:

  Through the analysis, limits and gaps in the current regulatory and standardization framework were identified. This step was critical in pinpointing the specific areas where existing standards were insufficient or where no standards existed.

  Key issues such as interoperability, efficiency, safety and security were highlighted, forming the basis for proposing necessary changes.

- Proposal of improvements or new legislation:

  Based on the identified gaps and limitations, proposals for improvements or new legislation were developed. These proposals aimed to address the shortcomings of the current framework and support the effective and widespread adoption of EV charging infrastructure.

  Recommendations included updates to existing standards, the development of new standards, and the harmonization of regulations across different jurisdictions to ensure a cohesive and supportive environment for EV deployment.

This structured methodology ensured a comprehensive and collaborative approach to addressing the regulatory and standardization needs, fostering innovation and supporting the expansion of EV charging infrastructure.

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3 WIRELESS CHARGING AND VEHICLE MODIFICATIONS

Wireless charging for electric vehicles (EVs) is an emerging technology that aims to simplify the process of charging EVs by eliminating the need for cables and plugs. Its main principle is the magnetic induction. The charging station counts with the primary coil/s, which generates an alternating magnetic field when an alternating current (AC) flow thought it/them. When the secondary coil, attached to the underside of the vehicle, is placed on or over the primary coil or track, the magnetic field induces an electric current in the EV's coil, which is then converted into direct current (DC) to charge the battery.

This technology presents clear benefits respect to the traditional conductive charging. EV's users can simply park their vehicles over a charging pad (static wireless charging), or drive along a charging track, without the need to plug in a cable, making the charging process seamless and user-friendly. It facilitates automated charging, which is particularly beneficial for autonomous vehicles (AV) and Connected Autonomous Vehicle (CAV) that can park themselves and initiate charging without human intervention. Avoiding cables manipulation, it reduces the risk of tripping hazards and exposure to weather conditions associated with cables.

The wireless charging technology counts also with some limitations that are in some cases related to its incipient status. While efficiency is improving, wireless charging is generally less efficient than wired charging, leading to energy losses that can affect overall charging speed and cost. Related to this, precise alignment between the vehicle and the charging pad is necessary for optimal efficiency, although new technologies are improving this aspect. The installation of wireless charging infrastructure can be expensive in terms of equipment and potential modifications to parking facilities. Currently, wireless charging systems typically provide lower power levels than fast wired chargers, which means longer charging times.

Currently, few electric vehicles are built with inductive battery charging systems, requiring physical modifications for installation, either for continuous use or for testing this emerging technology. Next sections provide the results of task 9.7 in relation to EV wireless charge and vehicle modifications regulations and standards analysis and improvement proposals.

3.1 Current regulations/standards

- SAE J2954: Wireless Power Transfer for Light-Duty Plug-in/Electric Vehicles and Alignment Methodology
    - Published in 20/10/20 as a standard
    - V.11 published in 29/8/22
- SAE J2954/2: Wireless Power Transfer of Heavy-Duty Plug-In Electric Vehicles and Positioning Communication
    - J2954/2_202212 published
- SAE J2954/3: Dynamic Wireless Power Transfer / Wireless Electric Road Systems for Light and Heavy-Duty Electric Vehicles
    - Acceptable criteria for D-WPT VA/GA specification: power class, efficiency, interoperability, electromagnetic compatibility, EMC/EMF, minimum performance, safety, and testing for WPT
    - Alignment and Activation Methodology, Guidance Systems
    - EMC/ EMF Differences between Static & Dynamic

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    - Link Both SAE J2954/1 & SAE J2954/2 Static WPT
    - Electrical and communications system definition of ERS layers
- SAE J2836/6 - Use Cases for Wireless Charging Communication for Plug-in Electric Vehicles
- SAE J2847/6 – Communication for Wireless Power Transfer Between Light-Duty Plug-in Electric Vehicles and Wireless EV Charging Stations
- UL 2750: Outline of Investigation for Wireless Power Transfer Equipment for Electric Vehicles
- IEC 61980-1: Electric Vehicle Wireless Power Transfer (WPT) Systems - General requirements
- IEC 61980-2: Electric Vehicle Wireless Power Transfer (WPT) Systems - Specific requirements for communication between electric road vehicle (EV) and infrastructure with respect to wireless power transfer (WPT) systems
- IEC 61980-3: Electric Vehicle Wireless Power Transfer (WPT) Systems - Specific requirements for the magnetic field wireless power transfer systems
- IEC 61980-4: Interoperability and safety of high-power wireless power transfer (H-WPT) for electric vehicles
- IEC 63243: Interoperability and safety of dynamic wireless power transfer for EVs
    - draft of the IEC 61980-5 renamed as IEC 63243
- IEC 63381 (IEC 61980-6): Communication requirements of D-WPT for electric vehicles
- ISO 5474-4: Electrically propelled road vehicles — Functional requirements and safety requirements for power transfer — Part 4: Magnetic field wireless power transfer — Safety and interoperability requirements
- ISO 19363: Electrically propelled vehicles — Magnetic field wireless power transfer - Safety and interoperability requirements
- ISO 15118-20: Road vehicles - Vehicle to grid communication interface - 2nd generation network layer and application layer requirements
- ISO 15118-24: Conformance tests for WPT use cases of ISO 15118-20

3.2 Limitations identified

- Clarification about the level of emissions needed. ICNIRP recommendations are taken as a standard, but limits change in ICNIRP 1998 or ICNIRP 2010. As an example, the French standard remains that of 1998; 2010 version must be evaluated, and the standards will be updated in consequence.
- Undefined EM emissions testing procedure. Not only maximum levels, but tested positions need to be defined.
- Interoperability undefined. Aspects regarding the polarity of the magnetic field (shape of the coils), frequency range, operational mode and others need to be studied and discussed.
- Efficiency measurement method undefined.
- Lack of standard for communication between charging station and EV for dynamic WPT use case. While ISO 15118 recommends the use of Wi-Fi and messages for the static WPT use case, it is not an adequate solution for the dynamic WPT due to several limitations. One significant issue is that communication between the vehicle and track will be lost at various points along the track.

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- Lack of standard for security requirements for dynamic WPT. Aspects like the manipulation of the devices inside the EV and the supervision of the track (presence of strange objects, EM emissions) is not defined.
- Lack of standard for static WPT systems above 11.1 kW. IEC 61980-3 classifies the IPT systems according to the input power classes originally defined by SAE J2954, which considers systems up to 11.1kW, and defines MF-WPT4 and 5 classes to be described in further editions.

3.3 Enedis Wireless charging – Power quality measurement in INCIT EV

EDF R&D and Enedis les 2 different measurement campaign on Vedecom site pour Wireless charging system in urban area (in November 2023 and February 2024).

The last test campaign demonstrated an improvement in the operation of the recharging solution, with less disturbance in the 9 to 150 kHz band. This shows the importance of a control system to limit the impact of disturbances. However, there is still a problem with the disturbance generated by the AC/DC converter at 70 kHz, which exceeds permissible compatibility levels.

As far as harmonics are concerned, it should be noted that, for this power level, the limits for harmonic current are not particularly strict. It is important to note that the test conditions were not entirely consistent with those that might be found in a laboratory environment.

Although the current standard (IEC 61000-3-12) does not specify a limit for even-current harmonics, it is clear that this technology induces a noticeable disturbance at these levels. This disturbance is directly linked to the switching of each coil, depending on the vehicle's power and speed. It is even possible to estimate vehicle speed based on these disturbances.

In the future, it will be necessary to carry out in-depth studies on this phenomenon, and to consider a change in standards to impose disturbance limits adapted to wireless recharging technology.

3.4 Proposed amendments and extensions to current regulation/standards

Table 2. Wireless charging and vehicle modifications proposed amendments and extensions to current regulation/standards

Type	Regulation/standards involved	Proposed solution
Update	ICNIRP	Evaluate the transition from ICNIRP 1998 to ICNIRP 2021 in the national implementation standards.

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		Establish a clear timeline and process for adopting ICNIRP 2010 recommendations, including stakeholder consultation and regulatory updates
Lack		Definition of EM emissions testing procedure, limits and measurement positions.
Lack		Definition of efficiency measurement method. VEDECOM proposes a method based on the energy sent or received by the EV per coil installed on the EV side and per kilometre in the case of DWPT charging.
Lack	ISO 15118	Development of a specific communication standard for dynamic WPT, focusing on reliable and continuous data exchange between the vehicle and the charging infrastructure. This standard could leverage advanced wireless communication technologies like 5G, which offers low latency and high reliability, to ensure uninterrupted communication.
Lack		Definition of security requirements for dynamic WPT, including aspects like the manipulation of the devices inside the EV and the supervision of the track (presence of strange objects, EM emissions).
Lack	IEC 61980	Definition of power classes above 11.1 kW. IEC 61980-3 defines MF-WPT4 and 5 classes to be described in further editions.

3.5 Future prospects and further recommendations

The INCIT-EV project's exploration of wireless charging technologies has revealed the need for a comprehensive and unified approach to standardizing these systems, particularly regarding electromagnetic emissions, efficiency, and interoperability. Establishing transparent, universally accepted protocols for testing and measuring performance is crucial. This will not only ensure safety and reliability but also facilitate the integration of wireless charging infrastructure across various regions and manufacturers. Engaging stakeholders from different sectors early in the standardization process can stimulate innovation, ensure compliance, and keep pace with technological advancements, especially in power transfer and communication protocols.

Additionally, it is recommended that the "owner" of a receiver design be responsible for verifying its interoperability with relevant designs through magnetic simulations and testing. Investigating the interoperability of the Electreon receiver against reference designs such as Witricity (SAE J2954), VEDECOM, and CIRCE transmitter coils is essential. These steps will ensure compatibility and enhance the reliability of wireless charging systems. Focusing on user-centric design and incorporating user feedback will improve usability, promoting global adoption of electric vehicles.

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4 BIDIRECTIONAL AND SMART CHARGING

Bidirectional charging is a feature that allows EVs not only to get energy from the grid but also to give it back (also called V2G, Vehicle to Grid). It offers numerous advantages for both EV owners and electric grid system; in fact, the first ones can use energy stored in EV to power up a facility or give it back to the grid when the energy price is higher, in order to obtain energetic and economic gains. From the electric grid system point of view, bidirectional charging, V2G, can contribute to balance the energy demand and supply. During peak consumption periods when energy demand is high, EVs can release the stored energy in their batteries to the grid providing grid management support. Bidirectional charging can also contribute to managing energy from renewable sources such as solar or wind power increasing renewable energy spread. This charge management adapted to grid state or other info is also called “smart charge”.

Besides these benefits, some limitations in current standards or lack of regulation to V2G and smart charge have been identified. Next sections list these limitations and lack of regulation while proposing some regulations and standards improvements to ease bidirectional and smart charge of EVs.

4.1 Limitations identified with current regulation/standards

- In development phase it's difficult to apply ISO 15118-20 because of the certificates needed: it is not possible to apply in full the norm if not all the certificates related to TLS are owned. These certificates are the vehicle certificate, the certificate chain of the OEM's PKI (OEM root CA certificate and Sub-CA certificates), and the V2G root certificate (from the charger manufacturer's PKI).
- Lack of reference to EVs response times to enable services e.g. fast frequency response.

4.2 Lack of regulation/standardization identified

Several errors within actual protocol do not have yet clear escape routes as:

- Not clear how to manage errors in “SupportedAppProtocol” phase, i.e. if EVCC doesn't offer "-20DC" namespace. (ISO 15118-20 [V2G20-2132]);
- Not clear how to manage errors in Authorization phase, i.e. if the “SelectedAuthorizationService” is not EIM. (ISO 15118-20 [V2G20-1583], [V2G20-2209], [V2G20-2219]);
- Not clear how to manage errors in “DC_ChargeParameterDiscovery” phase, i.e. if invalid parameters are exchanged or if “BPT_DC_CPDReqEnergyTranferMode” is not used. (ISO 15118-20 [V2G20-2272]);
- Not clear how to manage errors in “ScheduleExchange” phase, i.e. if “EVMinimumEnergyRequest” is greater than “EVMaximumEnergyRequest” or “EVTargetEnergyRequest”. (ISO 15118-20 / 8.3.4.3.7)

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4.3 Proposed amendments and extensions to current regulation/standards

Table 3. Bidirectional and smart charging proposed amendments and extensions to current regulation/standards

Type	Regulation/standards involved	Proposed solution
Update	Grid code	Grid code harmonization (now they are different in each country)
Update	ISO 15118-20	Conformance test implementation to guarantee interoperability
Update	ISO 15118-20	AC charging extension

4.4 Future prospects and further recommendations

V2G EV management development is not proceeding quickly because the standards are still incomplete and not all the use cases are covered. As a consequence, there is a problem of stacks development, in fact the availability of ISO 15118-20 compliant stacks is limited and only recently they are started to be produced and so tested within EVs.

It should be useful to activate a discussion forum between European commission and ISO to present and explain the potentiality of bidirectional charging to consider this EV feature in the investment decisions. Recently Europe has made available founds to develop fixed storage, that is countertrend with the V2G development; this could take industry to manage bidirectional charging with less effort, making this technologic development difficult and slow.

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5 GRID SUPPORT AND INTEGRATION

Grid integration is related with various topics that are important to facilitate the mass deployment of EV charging points with dense charging sessions. For Grid operators, standardization in the field of electromobility is key as it enables to handle the following strategic challenges:

1. Ensuring the safety of people and property
2. Controlling the impact of electromobility on the network
3. Ensure interoperability between charging systems and network management
4. Facilitate the development of related services
5. Guarantee grid security against cyber attacks
6. Facilitate Electric Mobility

Interactions between e Mobility functions, to be standardised (in blue) and DSO processes (in grey) are provided in the table below:

Table 4. Interactions between e mobility and Grid operator processes (from ENEDIS report)

	Safety	Cyber security	Smart Charging	Disturbances	V2G	Interoperability	Roaming
System control			x			x	
Asset Mangement	x			x	x	x	x
Metering		x	x		x		x
Smart Grids	x	x	x	x	x	x	x
Grid Codes		x	x	x	x		
Grid connection	x		x	x	x	x	x

Also, power quality is a key aspect, because the charging process cannot disturb the electric environment and must be immune to the overall noise level of the grid. These issues have been discussed in other sections of the document.

Finally, grid support is related to the functionalities that might be required to mitigate issues on the grid, either a consequence of the charging process itself, or other issues (such as massive connexion of distributed generation). These new functionalities are generally required in the "grid codes", which are often very local, and required by the DSO that operates a specific area. Usually, these functionalities (such as reactive compensation to help maintain the voltage) are required only to generating assets, not to loads, but as EV

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charge is/could be controlled, this is a new possibility that is expected from EV participation. Of course, the simple shift of the charging sessions to off peak times (incentivised through ToU ie Time Of Use tariffs) is the basic first step to facilitate the grid integration.

ToU tariffs exist in most of EU countries. In Germany, for example, a regulation for controllable loads (Heat pump, EV charger…) has been described. In France, ENEDIS has been using this incentive since the 80's. These tariffs are implemented and embedded within smart meter system. Furthermore, some controllable loads such as water boilers have been connected to the meter so then the water is heated automatically at off peak times, mainly by night. Therefore, it is easy to get chargers (as done for water tanks) directly connected to the smart meters, so then charging session will be automatically optimised.

Next sections provide the results of task 9.7 in relation to grid support and grid integration regulations and standards analysis and improvement proposals.

5.1 Limitations identified with current regulation/standards

The limitations identified within current applicable regulation and standards to EV charging stations grid integration and support have been grouped in 3 sections:

- Power quality
- Grid support
- Communications needs

5.1.1 Power quality

5.1.1.1 Charge setpoints for emissions assessment

In IEC 61851-21-x (EMC standards for electric mobility) and regulation R10.6 (related with the official EV homologation process), harmonic and flicker emissions are measured only at 80% of the rated currents, for example, 80% of 16A single phase and 80% of 32A three-phase if the on-board charger offer these possibilities.

For harmonics, the general tests conditions of the product standards EN 61000-3-2 and 61000-3-12 require performing tests at the setpoint which generates the maximum THC (Total Harmonic Current). In the standard dedicated to the EMC for e-mobility (IEC 61851-21-x), this requirement is not clearly mentioned. This should be corrected to ensure that harmonics are limited whatever the charging power.

It is widely recognized that a power electronic system operates effectively in terms of efficiency and power factor when operating close to the rated current. Despite the current lack of necessity for testing at low currents, there may be a need for such setpoints in scenarios like smart charging. It is recommended to introduce new setpoints, such as 20% of the rated currents, in addition to the traditionally chosen 80% for homologation reference R10. Some of these considerations were already raised in relation with smart-charging for example in the publication by ELAAD and ENEDIS, together with EDF R&D: https://elaad.nl/en/power-quality-guidelines/.

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5.1.1.2 Emissions assessment for EVSE above 75A per phase

Today, there are no applicable standard for the harmonics and flicker of the EVSE if the rated current of the equipment is above 75A. An EVSE manufacturer has no reference limit to design a charging station above 3x230x75=52kVA, so basically every fast-charging EVSE above 50kW.

The current consensus is that for high power equipment to be connected to the public low voltage distribution grid, an agreement between the installer and the distribution supply/network operator has to be made. It is also true that there are no “general-use” equipment of such power generally connected to the public LV grid, they are mainly connected to private installations which could be connected to medium voltage (or to LV grid, but considered appropriately by the DSO, because above a certain kVA threshold). Fast chargers are new in the landscape because they could be connected alone to a point of connection of the LV grid.

Furthermore, in current EMC standard for e-mobility, as the output power is clearly variable in relation with the EV-battery needs, standards for equipment above and below 16A are applicable, so for an EVSE above 50kW, EN 61000-3-12 and EN 61000-3-11 would be applicable (below 75A), but this is not yet made clear in the current standards.

5.1.1.3 Supra-harmonic (9kHz-150kHz) emissions

In some European countries, smart metering relies on PLC to communicate to the DSO, but there are no emissions limits for equipment in the “supra-harmonics” frequency range (9kHz-150kHz). The only published document is the EN 61000-2-2 for the compatibility levels.

As the EV charging process will be in the near future mass-market power electronic connected to the public LV grid, directly in residential premises, this is really important to limit the non-intentional emission in this frequency range. Furthermore, it is important to note that up to now, chargers (especially on-board-chargers) respect limits in the harmonics frequency range (below 2kHz), and in the radio-frequency range (above 150kHz), and the power electronic switching frequency of the AC to DC converter (charger) is generally somewhere between 10kHz to 50kHz, the probability to have high non-intentional emissions is clear.

The French DSO ENEDIS is currently already facing smart-metering communication issues in specific cases, and these are generally caused by small switch-mode power supplies (for example internet boxes power supplies), so it is crucial to limit NIE (Non-Intentional Emissions) for every equipment connected to the LVD.

5.1.1.4 Upcoming MegaWatt Charging Systems tests

These new very high-power chargers for heavy-duty vehicles need to be properly connected to the grid, and existing EMC test-labs would need to be updated to test the requirements of IEC 61851-21-2, which is currently not dealing with on-site tests. In addition, another way to assess the emissions would be to make the tests once installed but this is clearly not the way tests-labs are used to. MCS early adopters could nevertheless use this option. EMC is highly related to well-known, reproducible test conditions in labs, especially for high frequencies, once in the field, the tests should be performed for every new installation, so no more talking about equipment type-tests.

5.1.1.5 Bi-directional charging requirements (for V2X)

Apart from off-grid functions (vehicle to load or vehicle to an islanded installation) which are not a “grid integration” topic, discharging an EV needs to be considered and has to use similar rules as generators (IEC

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61000-3-16 has been recently published by IEC SC77A/WG1). Also, even if the network code published by European Commission “Requirement for Generators” does not currently concern vehicle to grid, it is foreseen for the next revision of this regulatory text.

5.1.1.6 Enhancement of charging immunity

The grid is disturbed by all the new usages relying on power electronics and also by other phenomenon (short-circuits which generates voltage dips, storms which generate very high transients…). To make sure end-user have a correct experience with their EV, it is very important that OEMs make robust products. Today, there are not a lot of requirements in the standards dedicated to electric mobility, but even if it is clearly part of manufacturer’s know-how, it is also important to highlight this point. It is indeed clear that the grid quality can be perturbed in some cases, leading to sudden voltage drops, or high total harmonic distortion: clarifying what is expected of the charging process is then very important.

5.1.1.7 ENEDIS Wireless charging – Power quality measurement in INCIT EV

EDF R&D and ENEDIS conducted two different measurement campaign on VEDECOM site for Wireless charging system in urban area (in November 2023 and February 2024).

The last test campaign demonstrated an improvement in the operation of the charging solution, with less disturbance in the 9 to 150 kHz band. This shows the importance of a control system to limit the impact of disturbances. However, there is still a problem with the disturbance generated by the AC/DC converter at 70 kHz, which exceeds permissible compatibility levels.

As far as harmonics are concerned, it should be noted that, for this power level, the limits for harmonic current are not particularly strict. It is important to note that the test conditions were not entirely consistent with those that might be found in a laboratory environment.

Although the current standard (IEC 61000-3-12) does not specify a limit for even-current harmonics, it is clear that this technology induces a noticeable disturbance at these levels. This disturbance is directly linked to the switching of each coil, depending on the vehicle's power and speed. It is even possible to estimate vehicle speed based on these disturbances.

In the future, it will be necessary to carry out in-depth studies on this phenomenon, and to consider a change in standards to impose disturbance limits adapted to wireless recharging technology.

5.1.2 Grid support

5.1.2.1 Smart charging capability

Especially for on-board-chargers, it is important that the charging process reacts quickly and accurately to a modification of the current setpoint sent by an external signal. Tests in labs have proven that not every EV reacts the same. There are requirements in IEC 61851-1 but not strict. Time-responses for the EV to react to an EVSE setpoint modification through the control pilot line are quite slow. Also, the only requirement for the current regulation accuracy is only not to go over the limit sent by the EVSE.

Again, as mentioned in an ELAAD/ENEDIS study, it could be a good procedure to create a “smart charging ready label”, but this is not a standard/regulation process, more a “quality” branding such as EV-ready in France.

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5.1.2.2 Reactive power adjustment

In ISO 17409, the standard dealing with the safety of the charging process, from the EV perspective, there are several functional requirements in addition to the safety requirements. One of these is the following: if the vehicle is able to adjust the reactive power, it shall adjust it at the setpoint sent by the charging infrastructure (through ISO 15118-2) in a given range (with a cos(phi) between 0.9 and 1, inductive or capacitive), with various rules such as Q=f(U), cos(phi)=f(P) or tan(phi) as a fixed value.

This requirement is mandatory in Germany for chargers above 12kVA, and not explicitly limited to bidirectional technologies.

5.1.2.3 Active power adjustment with the frequency for V2G

In the to-be-released revision 2 of the Requirements for Generators regulation ("RfG v2"), there are now explicit requirements for V2G technologies (considered a specific subcase of electric storage, able to consume or supply electricity), with a classification in 3 categories: EV1 from 800W to 2.4kW, EV2 up to 50kW and EV3 up to 1MW.

Some of these requirements may pose challenges to meet, particularly the one associated with the "Limited Frequency Sensitive Mode". This stipulation is mandated by Transmission System Operators (TSOs) to safeguard grid stability concerning the acceptable frequency band centered around the standard value of 50Hz. When the frequency surpasses a specified threshold of 50.2Hz, the system must decrease the power it supplies to the grid through a linear frequency-dependent function, while below 49.8Hz, it should diminish its power intake (during charging) using a similar linear approach, extending even to power supply mode (during discharging) up to the maximum available capacity.

Despite the relatively "low" setting of the droop, for instance, 5% (where the entire power modulation is within 5% of 50Hz, equivalent to 2.5Hz), swift responsiveness is essential, necessitating a comprehensive evaluation of the entire Electric Vehicle and Electric Vehicle Supply Equipment (EV+EVSE) system to validate this response, incorporating a specified Rate Of Change Of Frequency (ROCOF).

These emerging criteria have yet to be incorporated into the pertinent standards (primarily emanating from ISO TC22 and IEC TC69).

5.1.3 Communication needs

Controlable loads such as water tanks, EVs and heat pumps are seen as appropriate means for power system flexibility, especially for TSO grid services. Markets for ancillary services, such as system balancing exist already (for instance the NEBEF mechanims is deployed by the French TSO RTE Participate in the NEBEF mechanism - RTE Services Portal (services-rte.com)), to which for instance a fleet of EVs could participate if enough load shifting potential is gathered. However, it is quite rare to see market for local services, which aims to relief grids assets constraints, as LV assets have lower value to stimulate a profitable market.

However, negociations with DSOs can be made case by case for flexibilty contracts, reducing power capacity at some peak times. Some innovative connection agreements have been made at MV level at Enedis (mostly for Distributed Generators), and we can foresee different ways to do so for connexion of future charging infrastructure to the distribution grid.

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Therefore, to activate any flexibility call, it is needed a harmonised and standardised communication channel within the whole communication chain connecting Electric Vehicle, EV Supply Equipment, charging point operators and DSOs (as shown in Figure 1).

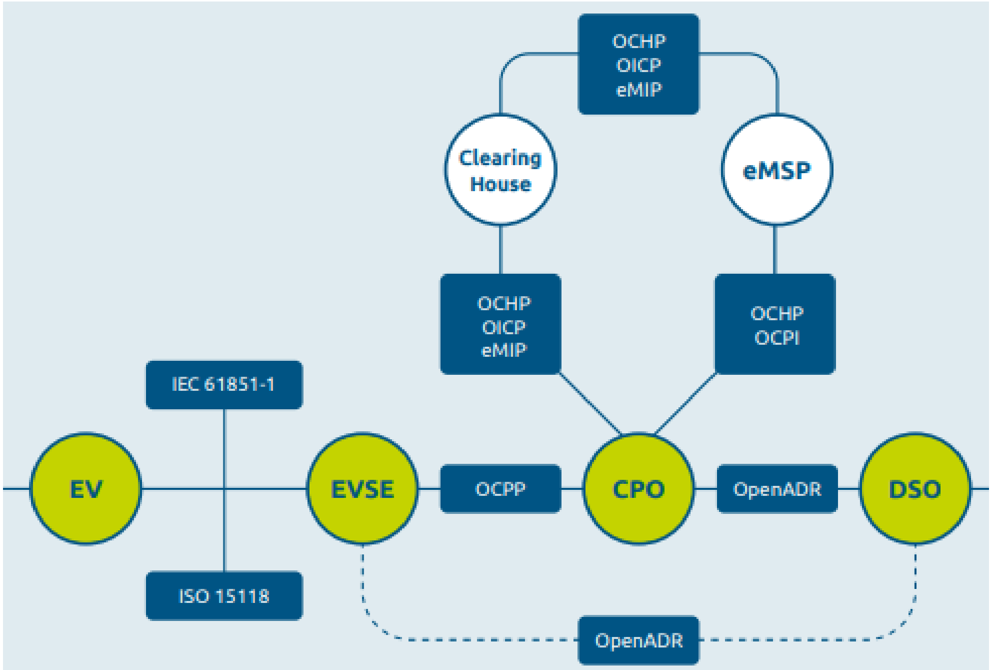

Figure 1. Overview of the most dominant communication standards and protocols related to EV charge.

This figure is extracted from stakeholder analysis report, produced by the EU Horizon SCALE project, it is a high level figure showing the main protocols used for EV charging. For more details, we refer to the report D1.4 - Publications - SCALE (scale-horizon.eu). In the next paragraphs, the main standards which have been defined to ease the communication between each sub system are highlighted.

5.1.3.1 Vehicle to EV Supply Equipment communication: ISO 15118 - IEC 61851-1 standards

While there is an ever-wider interest in implementing ISO 15118-like communication between EV and EVSE, most of what is seen in the field is still in DC fast charging with DIN 70161 for the moment. Bidirectionality pushes industrials to think about and implement ISO 15118-20. An amendment is currently being written to cope with new grid code regulations in the US and to correct some issues seen on the field. But this takes time.

On the other hand, Plug and charge functionality is driving the market toward the implementation of ISO 15118-2. This induces also some different communication needs for the exchange of certificates for PnC (Plug and Charge) authentication between actors of the ecosystem. Different PKIs are being set up in Europe, and also in the US and Asia. To exchange those certificates between the different actors, CharIN is preparing a new protocol called OPNC. Convergence toward this protocol could help actors of the e mobility to flexibly choose their supplier of PKI services but remains uncertain as of today.

Compared to IEC 61851-1, ISO 15118 allows the EV and charging station to dynamically exchange information based on which a proper charging schedule can be (re-)negotiated.

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5.1.3.2 EV Supply Equipment supervision: OCPP – IEC 63110 standards

On the supervision side, while OCPP 2.0.1 has been specified years ago, there are few implementations on the market. Most EVSE manufacturers are still working with OCPP1.6. Subsidies tied to OCPP certification in some countries are incentives that work in driving the change toward OCPP2.0.1. However, there is lot of feedback toward OCPP specifications, that show that interoperability is still something to fight for. This is needed to provide infrastructures that are reliable, well supervised and that can last longer in the time. This also allows EVSEs to be controlled in terms of smart charging. This functionality is not envisioned to be widely used for fast charging, but smart charging is a great asset for the grid in use cases like charging at home or in businesses. OCPP 2.1 is still being worked on by the OCA. The main new functionality will be V2G, but this version will provide a lot of small features. This version will be backward compatible with OCPP 2.0.1 and will therefore be easier to implement step by step by the industry. Since 2023 OCA is making a merging work to include IEC 63110 requirements within OCPP standard.

5.1.3.3 EV Flexibility aggregation: OCPI and IEC 63382 standards

In the future, it can be foreseen that there will be different types of flexibility aggregated (consumers, storage, HVAC, EVs, and maybe more) and different actors supervising them. In the e-mobility sector, some actors will specialize in the aggregator role, and other in the supervision of EVSEs, these actors will need to exchange data about the available flexibility. Standardization of those interfaces is advisable. Work on this in the EV roaming foundation and OCPI has to be made, but also in IEC 63382 working group. Convergence of those 2 working groups would help the market to grow interoperable and would lower overall cost of this kind of flexibility.

5.1.4 Standards used by DSOs for e Mobility

The table below summarizes the main standards related to grid integration for e Mobility and interfaces.

Table 5. Summary on standards used by DSOs for e Mobility

Norm Reference	Description and purpose
IEC 60870-5-104	Communication protocol used by Enedis for communications with the control system.
IEC 61850	Definition of communication protocols associated with control equipment in Smart Grids.
IEC 61851	Electrical safety standard for AC (-1) and DC (-23 and -24) electric vehicle charging equipment (mainly charging stations), with -21-1 and 2 covering EMC for charging stations, and -23-3 for the Megawatt Charging System (MCS for charging electric trucks).
IEC 15118	Communication protocol between the Electric Vehicle and the charging station.
IEC 63110 (or OCPP)	Communication protocol between the charging station and the CPO system

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IEC 62786-1, -2 & -3	To connect bi directionnal EVs capable of re-injection (conditions for connecting decentralized energies (DER): batteries and solar), such as RfG. A version for electric vehicles is planned.
IEC 63119	To assure roaming of Evs including contract for energy supply
IEC 63380	Deals with EMS including Eebus links to the charger
IEC 63382 (or OpenADR)	Describes data exchange between flexibility actors and CPOs

5.2 Lack of regulation/standardization identified

As e mobility sector is quite recent, there has been some lacks of regulation, lacks of implementation procedures, qualification of device readiness and some redundancies in the standards. Major issues and feedback have been raised through consultation EU proposition, which led to new updates of EU regulations such as:

- AFIR regulation
- EPBD directive
- ACER recommendation for V2G …

In addition to EU regulation, some countries (UK, France, Germany) have made further choices especially regarding smart charging requirements. In France smart charging readiness and connection to the meter are incentivized by subsidies (as tax reduction) for charger installation at households.

There are still some inquiries in the regulation that create some confusion, mainly for their lack of precisions (implementation). On standardization, there are some redundancies, for instance on communication data and interfaces and some lacks, for instance on Power Quality requirements:

- Implementation: regulation is well defined for purposes but do not provide enough precision and the know how to implement the requirements. For instance:
  - Smart charging readiness, implementation and certification: how to double check devices and their installation are really compliant with the requirements as listed on regulations texts
  - Cybersecurity check for installation: how to make sure subsystems which are connected to essential systems are really cyber protected
- Standards overlapping- redundancy: there are several standards which are aiming to respond to the same need while some of specificities are not overlapping.
  - For instance, OCPP and IEC 63110 were aiming to develop the Communication protocol between CPO systems and EVSE.
  - And OpenADR and CIM Market data models which aim to provide Communication Interface for flexibility services.

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- Grid disturbances: as EV is a new usage, we foresee some disturbances due to its co habitation with the Grid. ELAAD labs in the NL, EDF Labs in France and ENEDIS are doing a lot of testing to improve the integration of EVs to the grid.

5.3 Proposed amendments and extensions to current regulation/standards

Things have been a lot improved for EV integration, but there are still some work to do for future mass deployment of EVs, and some standards have to be adapted to include new requirements.

Power quality: it is recalled here the work done jointly by Enedis and Elaad on Power quality in e Mobility https://elaad.nl/en/power-quality-guidelines/.
We high light here major recommendations mainly:
#2 - Integrate Smart Charging in the research and standardization of harmonic emissions (about **IEC 61000-3-2** standard defines the harmonic current limits)
#3 - Integrate Smart Charging in the research and standardization of supraharmonic emissions (about **61000-2-2 standard** future evolution)
#6 - Adapt charging power to voltage levels (about **IEC 50160** evolution on voltage limits)

The table below gathers the needs for the evolutions listed above and more recently the needs to adapt grid codes to V2G.

Table 6. Grid support and grid integration proposed amendments and extensions to current regulation/standards

Type	Regulation/standards involved	Proposed solution
Update	IEC 61000-3-12	Limitation for wireless charging
Update	IEC 50160	Adapt charging level to voltage level
Update	IEC 61000-3-2	Integrate smart charging in harmonics standards
Update	IEC 61000-2-2	Integrate smart charging in supra harmonics standards
Update	RfG	Requirement for Generator to be adapted to V2G
Update	Grid code	Electrical installation procedures to be adapted to V2G

5.4 Future prospects and further recommendations

From the perspective of Grid operation, the current endeavor is concentrated on Vehicle-to-Grid (V2G): Grid Codes and RfG (Requirements for Generators) have been introduced by ACER and are presently being managed by a Working Group headed within the EU DSO Entity, with the participation of ENEDIS representing the French sector.

The cornerstone of electromagnetic compatibility lies in standardization: chargers capable of operating universally without causing problems to the grid. Initially, experts must compile all malfunctions witnessed in their laboratories or in practical scenarios. It is imperative to scrutinize the phenomenon for technical rectification and prevent its recurrence through standardization.

Demonstrators or consortia frequently pose challenges and necessitate a considerable amount of time for establishment, leading to a limited timeframe for conducting actual tests. Extending the duration of

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demonstrators/consortia could be a subject worth exploring to leverage the time invested in defining and establishing demonstrators.

Reaching a consensus on Power Quality standards is also an important task, as conflicting viewpoints among various stakeholders typically arise. Manufacturers of equipment strive to alleviate the burden of overly stringent requirements that would entail significant costs for implementation, while utilities must demonstrate that overly lenient standards would result in an unacceptable frequency of EMC issues in practical scenarios. Once more, full-scale demonstrators are indispensable for determining the optimal level of EMC, incorporating emission limits that are sufficiently low, and achievable immunity levels for Electric Vehicles (EVs) on-board chargers and EVSE power converters.

In the realm of wireless charging technology, as evidenced earlier by the disturbances detected by ENEDIS and EDF R&D due to the INCIT EV Use case, it is advisable to conduct thorough investigations into this occurrence and contemplate revising standards (such as IEC 61000-3-12) to enforce disturbance thresholds associated with wireless recharging technology.

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6 DC INTERCONNECTION

During the last few years, a resurgence of DC current deployment has notably made its way inside the whole electricity consumption balance, with Europe being no exception. This is not unexpected since the devices that use electricity have shifted dramatically towards consumer electronics. Power generation and consequently transmission also has seen an increased share of DC thanks to the renewable energy sources production increase and technological advancement. Nevertheless, many issues remain present, as the shift has regarded technology and its applications more than the existing standards: as often happens, regulations follow innovation.

The following paragraphs highlight the results of task 9.7 in relation to DC interconnection regulations and standards analysis and improvement proposals.

6.1 Limitations identified with current regulation/standards

Only few regulations at EU level are dedicated to DC transmission and distribution.

In electric energy distribution field, more specifically, the current reference document is the Commission Regulation (EU) 2016/1447 of 26 August 2016, that defines a general guideline and some regulatory principles regarding the standardization and the requirements for HVDC systems and connected DC generation parks among all EU member states, with the guiding principle of non-discrimination and homogenization aimed at future cooperation activities between multiple EU member states in HVDC generation and distribution.

Other guidelines are emerging recently due to the activities of the Strategic Energy Technology (SET) Plan that gathers many different regulatory bodies from EU states in 14 working groups, with renewable energy sources, HVDC, smart DC microgrids, electrification of vehicles and batteries technology and supply chain among others related to DC grid regulation.

At Italian level, for example, the CEI (Italian Electrotechnical Committee) rules regarding Low and Medium voltage connections in distribution matters (CEI 0-21; CEI 0-16) do not specifically contemplate native DC connections with POD dignity, only focusing on AC distribution. Thus, for the objective of UC-4 in Torino Caio Mario Park, it was deemed necessary to start an interaction with the authorities. Moreover, the UC-4 demo site architecture involves tramway traction (this applies also to railways in general), and the excise duty regime is different for the public transport sector compared to any other distribution, with lower taxes as the energy is deployed for a public service purpose.

6.2 Lack of regulation/standardization identified

The lack of regulation on DC direct connections at EU and at Italian level is an issue that must be addressed as the renewable energy sources production will increase and as DC microgrids spread seems to be a reality. See for instance the work of CurrentOS, a DC microgrid-fostering project that involves many of the most prominent companies in the electricity industry, from manufacturers to DSOs to multi-services.

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Concerning directly the UC-4 of the INCIT-EV project, there is a lack of regulations for the creation of a DC native distribution points, for example the one that was created to power the DC native charging infrastructure installed in the Caio Mario Park.

6.3 Proposed amendments and extensions to current regulation/standards

Table 7. DC interconnection proposed amendments and extensions to current regulation/standards

Type	Regulation/standards involved	Proposed solution
Update	CEI 0-16; CEI 0-21	Request to ARERA (Italian energy market authority) for exemption from the usual AC distribution standards and regulations (in Italy: TIMOE, TIME, TIQE etc.) as the connection is DC-DC. Request to the Italian customs agency (ADM) of formal authorization to operate both the DC connection and the DC meter as mean to balance the expenses sustained between main POD and INCIT-EV DC POD with added excise duties (as the energy is used for EV recharging and not public transportation tramway traction).
Update	IEC 62053-41	Necessary to improve the regulation with more precise directives regarding DC metering.

6.4 Future prospects and further recommendations

The INCIT-EV project proved to be not only innovative on the technological standpoint, but also in regulatory terms. The innovation proposed in UC-4, Torino Caio Mario Park, is focused on the peculiarity of DC tramway networks, that effectively can act as a not-so-micro DC grid spread among the surface of a city or metro area. Since the DC world is not contemplated as of now in distribution standards, a lot of work can be done, and in fairness is being done, at EU level concerning these fields.

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7 PAYMENT SYSTEM

Payment is an important topic in e-mobility and EV charging. Different flows of payment and different types of tariff structures have been worked on in T5.3 and described in D5.3 & D5.9. the next section focuses on regulation and standardization related to payment systems, and the limitations and lack of regulation identified.

7.1 Limitations identified with current regulation/standards

- OCPI protocol does not allow for feedforward information on tariffs and only communicates the actual tariffs. Often, tariff changes have to be communicated a month in advance. This is impossible with OCPI.
- Lack of/gap in standard protocols to integrate payment terminals, both for cloud-to-cloud and hardware-to-hardware payment terminals. Every Payment terminal company in the market requires separate adaption/integration. Payment terminals are a valuable solution for EV drivers. There is a trend that integrations are based on OCPI. However, OCPI currently does not have all the required functionalities described. Therefore, a gap in the protocol obstructs the number of payment terminals that are integrated, installed and used.

7.2 Lack of regulation/standardization identified

- Open standards to communicate electricity prices/tariffs, especially with dynamic energy contracts where electricity prices vary every hour and can be negative. This makes accurate reimbursement for these contracts virtually impossible.
- Lack of knowledge and standardization on clear tax ruling regarding home charging reimbursements. Also see working group of eViolin on this topic: https://www.eviolin.nl/wp-content/uploads/2023/06/Home-Charging-Compensation-NL-May-2023- -eViolin.pdf
- For Time of Use tariffs (being able to set and communicate prices on a fifteen-minute basis) to work efficiently, it is required that charging stations are configured to clock-aligned meter values (meter values are sent to the backoffice at set intervals (15 mins), this way energy per interval can be accurately calculated). Certain CPOs do not support clock-aligned meter values. This hinders giving EV drivers price incentives to charge at other moments
- Certain parties in the market don't follow the country code, party id setup. For example, CPO NL-ABC has chargers in Germany, United Kingdom. Because of this, identifying the correct currency and/or VAT rate for the eMSP can sometimes be challenging.
- Advanced charge stations have a display that can, for example, be used to show the tariffs at the station (often DC charging). Currently, there is a lack in protocol for sharing price information from the charge station backend to this display. Standardisation in this is crucial to effectively support price transparency.

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- Rules/regulation to refund pre-auth amounts (via app or via payment terminal) effectively and in time are currently not present. There are too many cases where the pre-auth amount never gets credited/refunded to the end user and the end user then has difficulties contacting the right party to get support. There should be clear regulations in place to prevent this.
- Instructions for the end user about the different payment options on the charger's display are often unclear or unstructured and therefore confusing. There should be standardisation regarding the communication about payment methods to end users (and related differentiated pricing).

7.3 Proposed amendments and extensions to current regulation/standards

Table 8. Payment systems proposed amendments and extensions to current regulation/standards

Type	Regulation/standards involved	Proposed solution
Update	OCPI	Implement feed forward tariff communication via OCPI.
Update	New	Develop an open standard for communicating electricity prices, especially with dynamic pricing.
Update	Energy Taxation Directive	Prevent double taxation of electricity by removing taxation for electricity that is supplied back to the grid.
Lack	New	Development of an open standard for communication between payment terminals and charge station backends.
Update/ Lack	New/AFIR	Mandatory support of clock-aligned meter values of charge stations.
Update/ Lack	New/AFIR	Regulation to only allow charge stations to use the Country Code of the Country they are located in.
Lack	New	Protocol for sharing tariff information between charge station backend and displays at a charge location.
Lack	New	Regulation regarding refunding of pre-auth amounts when using ad-hoc payment via an app or payment terminal
Lack	New	Standardisation regarding the communication about payment methods to end users (and related differentiated pricing)

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7.4 Future prospects and further recommendations

For the future, an increasing use of direct payment via payment terminals and smart charging is expected. At the same time, authentication and payment via ISO15118 is on the horizon. Proper incentives for participating in smart charging are in some cases difficult in the realm of public charging. Enhancing these capabilities via regulation and standardization will increase transparency and rewards towards EV drivers and will increase the capabilities of charging infrastructure. Ultimately, this will lead to a better user experience and increased uptake of electric vehicles.

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8 CONCLUSIONS

This deliverable D9.9, "Regulation and Standards Recommendations on Electric Infrastructure Charging," provides a comprehensive analysis and set of recommendations aimed at addressing the regulatory and standardization needs for the widespread adoption of electric vehicles (EVs) across Europe. The findings and recommendations are based on extensive research and the demonstration of various use cases within the project.

In this task, recommendations have been meticulously formulated with regards to the standardization and regulatory frameworks governing the domain of electric mobility. The focus has been directed towards two primary exigencies in the realm of standardization: firstly, the identified deficiency in established regulations that serve as catalysts for fostering innovation within a specific domain, and secondly, the imperative need to review and expand upon particular standards or regulatory measures. Subsequent to the culmination of all the exemplified utilization scenarios and the corresponding ramifications being seamlessly amalgamated into the Decision Support System (DSS), a comprehensive array of recommendations has been disseminated to expedite the process of updating both European and global regulations pertaining to charging technologies, as well as urban and vehicular adaptations.

The work in this task has been segmented into distinct categories based on the various topics of interest pertinent to the overarching project goals, with a particular focus on the strategic enhancement and proliferation of Electric Vehicle (EV) charging infrastructure. The allocation of responsibilities within this task has been carefully determined by taking into consideration the specific roles and levels of involvement of each team member in the execution of assigned duties and the showcasing of prototypes within the project framework, in conjunction with the unique expertise and competencies that each collaborating partner brings to the table. The main working topics have been:

- Wireless charging and vehicle modifications
- Bidirectional and smart charging
- Grid support and integration
- DC interconnection
- Payment system

Through a comprehensive examination and detailed scrutiny of the norms and standards that are pertinent and relevant to each of the aforementioned fields, a multitude of restrictive facets or areas characterized by a dearth of regulatory oversight have been pinpointed and brought to light. As a result of this discerning analysis, various enhancements and modifications have been suggested and put forth with the aim of enabling and promoting a broad and extensive dissemination and proliferation of electric vehicle (EV) charging infrastructure and facilities.

To guarantee the efficient implementation of the recommendations, it is imperative to maintain active involvement with stakeholders, such as standardization bodies, regulatory agencies and industry participants. The establishment of mechanisms for ongoing monitoring and revisions of standards and regulations is critical to remain abreast of technological advancements and market demands. The promotion of pilot projects and demonstrations can assist in assessing and enhancing new standards and regulatory frameworks prior to widespread adoption. These measures can significantly expedite the deployment of

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electric vehicles and charging infrastructure throughout Europe, thus contributing to a sustainable and effective transportation network.

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9 REFERENCES

** This document provides the results of a regulations and standards review applying to EV framework. This document does not provide a specific "References" section is as in every chapter, from 2 to 7, a specific list of the regulations and standards used is provided.*

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